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A Four-Step Ortho-Rectification Procedure for Geo-Referencing Video Streams from a Low-Cost UAV

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Introduction

- **What?**

Ortho-rectification is the process of geometrically correcting an aerial image such that the scale is uniform.

- **Why?**

Ortho-rectification and geo-referencing are essential to pin point the exact location of targets in video imagery acquired by the UAV

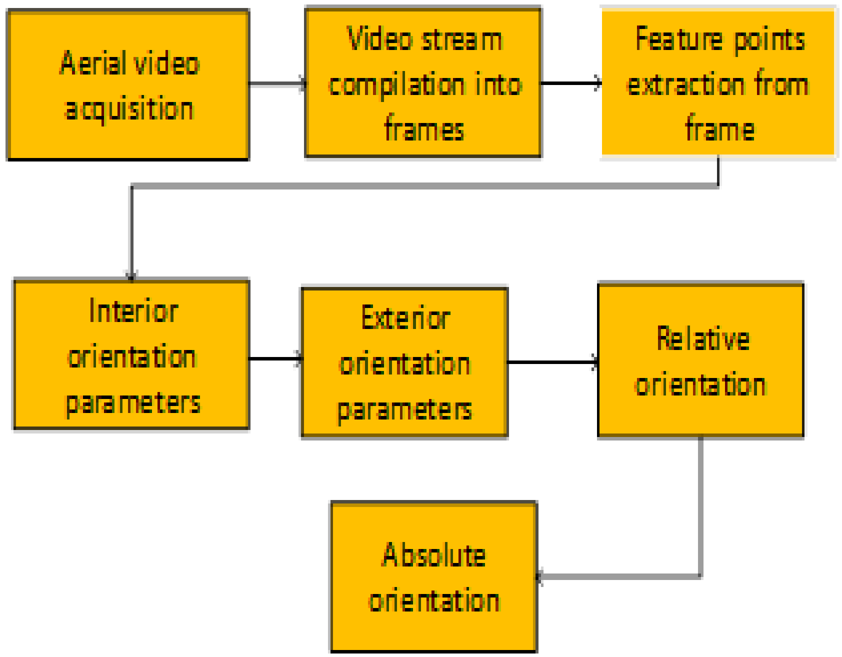
- **How?**

This can only be achieved by comparing the UAV video imagery with an existing well referenced map.
However, it is only when the image is ortho-rectified with the same co-ordinate system as an existing map that such a comparison is possible.
The method used in this paper is based on the photogrammetry model, this is a form of geometric imaging system that makes use of the aerial image central perspective and the principle of collinearity.

Introduction (cont.)

The four basic step for ortho-rectification and geo-referencing of video streams captured by a low-cost multi-sensor UAV:

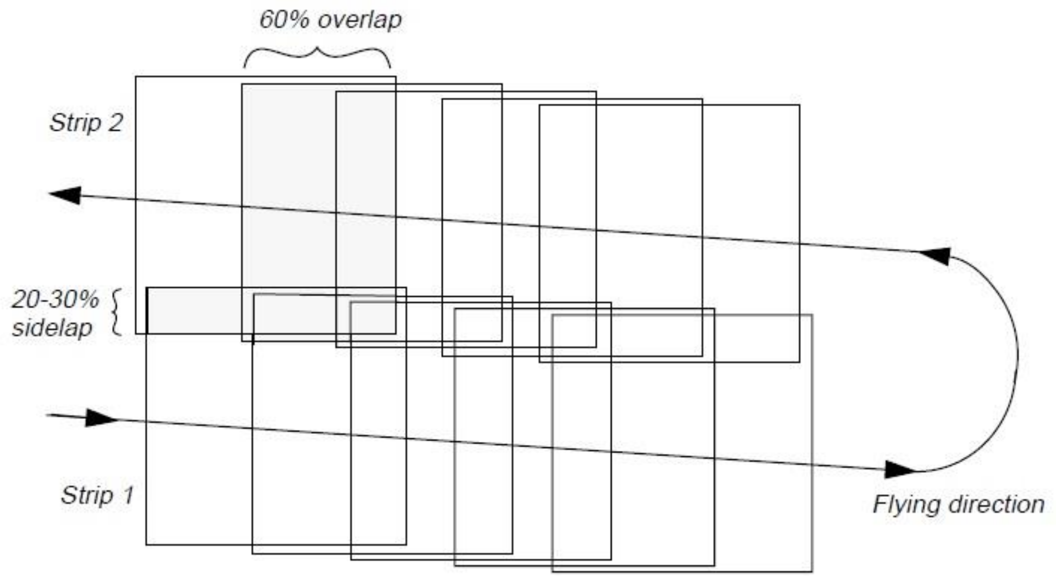
- De-compilation of video streams
- Establishing the video camera interior orientation parameters(IOPs)
- Determining the relative orientation parameters of each video frame
- Find the absolute orientation parameters using self-calibration bundle adjustment



Procedure workflow

Decompilation of video streams

- BPS video converter Software
- Feature points extraction and tie points matched



Courtesy ERDAS Field Guide

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Finding the interior orientation

- Interior orientation is basically used to transform the image coordinate system to the image space system
- It defines the internal geometry of the camera as it existed at the time of data capture
- The internal geometry of the camera is defined by 3 parameters:

  1). Principal point

  2). Focal length

  3). Lens distortion

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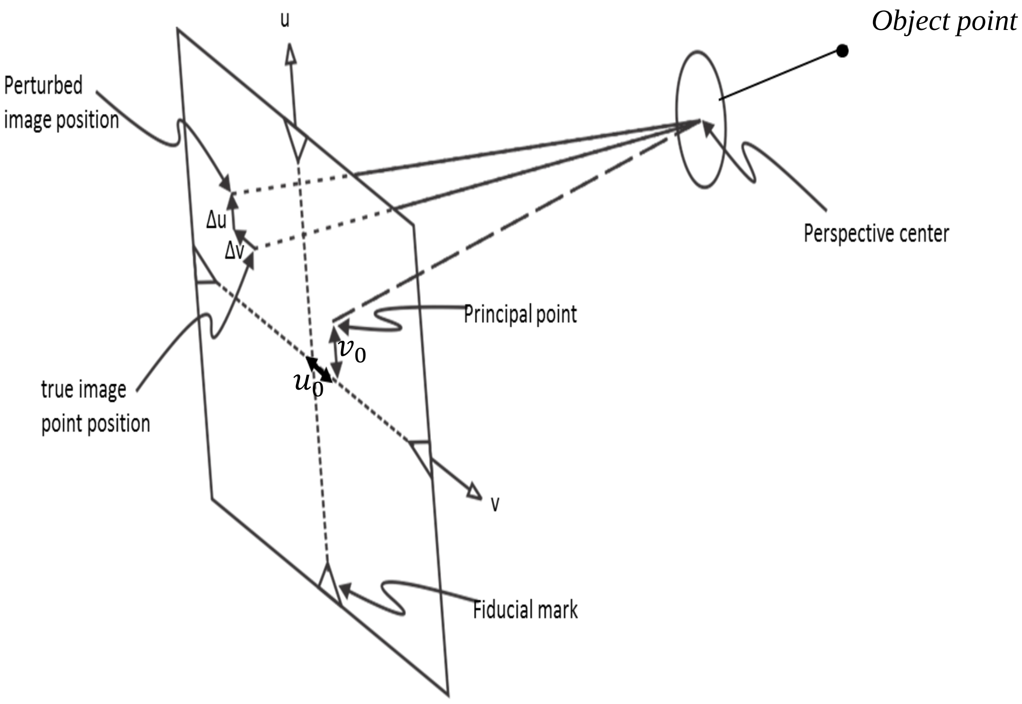
Finding the interior orientation (cont.)

- *Image point offset*

In the simplest terms, finding interior orientation involves shifting the actual point to satisfy the collinearity conditions



Interior orientation and the effect of perturbations to collinearity

Finding the interior orientation (cont.)

This collinearity condition is used by the Direct Linear Transformation (DLT) to facilitates a perspective projection between the 2D image data and the 3D object space, it requires foreknowledge of 3 ground control points and is of the form:

$$u - \Delta u = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

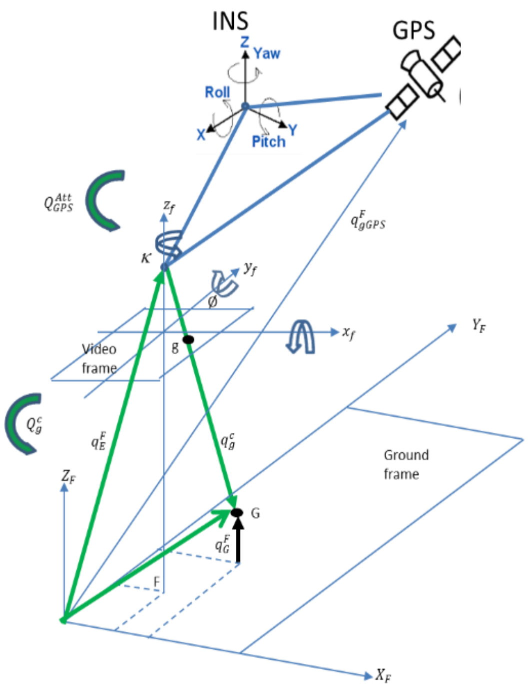
$$v - \Delta v = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

Finding the interior orientation (cont.)

- *Orientation offset between camera sensor frame*

This is express by (Guoqing) as:

$$q_G^F = q_{GPS}^F(t) + Q_{INS}^F(t)[S_F * Q_C^{INS}(q_g^C(t) + q_{GPS}^C)]$$



Geometric Relationship between GPS/INS, Video frame and the 3D world coordinates

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Finding the interior orientation (cont.)

- *Orientation offset between camera sensor frame*

$$q_G^F = q_{GPS}^F(t) + Q_{INS}^F(t)[S_F * Q_C^{INS}\left(q_g^C(t) + q_{GPS}^C\right)]$$

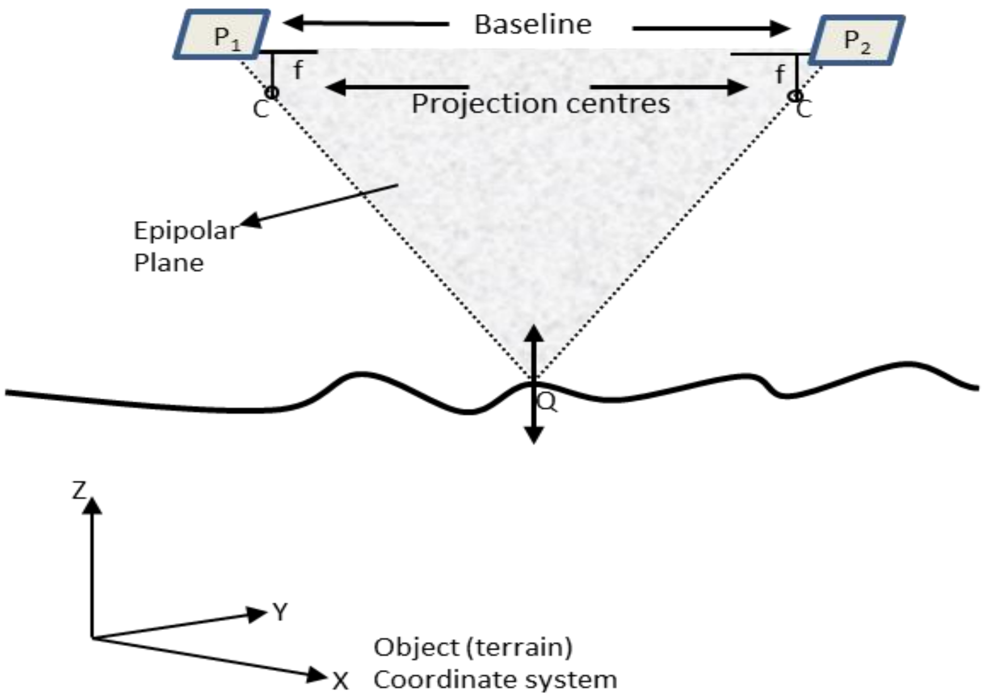
$$Q_{INS}^F = \begin{bmatrix} \cos\phi\cos\kappa & \cos\psi\sin\kappa + \sin\psi\sin\phi\cos\kappa & \sin\psi\sin\kappa - \cos\psi\sin\phi\cos\kappa \\ -\cos\phi\sin\kappa & \cos\psi\cos\kappa - \sin\psi\sin\phi\sin\kappa & \sin\psi\cos\kappa + \cos\psi\sin\phi\sin\kappa \\ \sin\phi & -\sin\psi\cos\phi & \cos\psi\cos\phi \end{bmatrix}$$

In this step, the camera calibration process considers the focal length and principal point coordinates only, because the IOPs and EOPs that was solved by DLT and the boresight values will be used as initial values for the final bundle adjustment model.

Finding the Relative Orientation

- What is relative orientation?

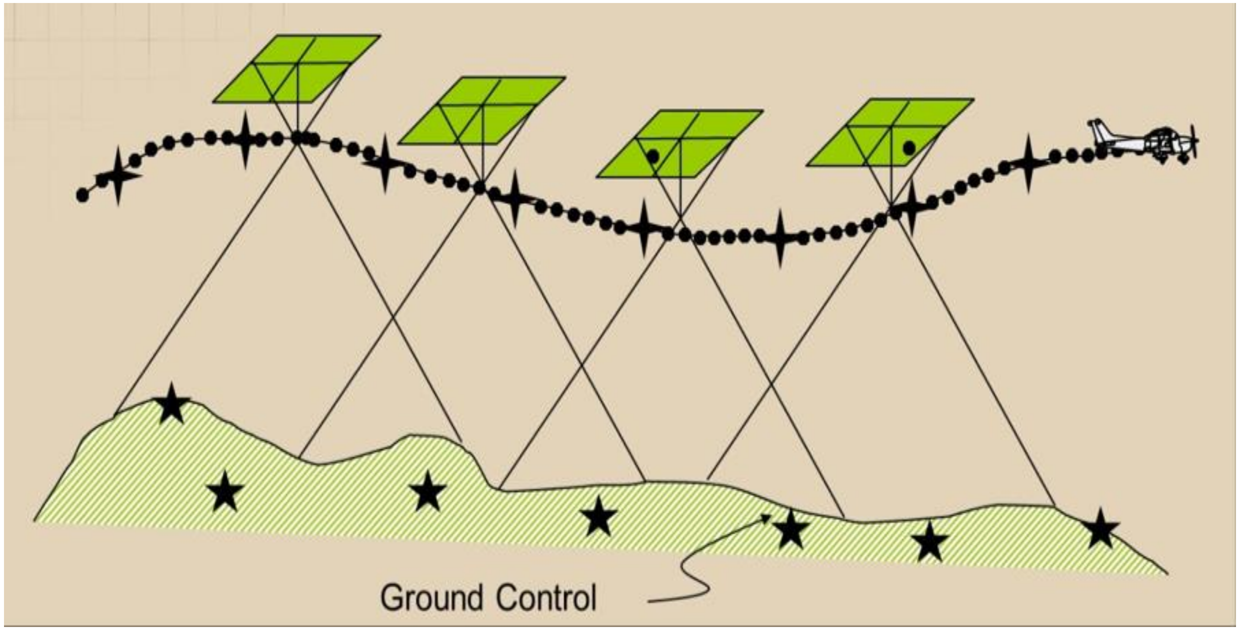
- How is this achieved?



stereoscopic viewing with two different camera positions

Finding the Absolute Orientation

- Absolute orientation
- Self-calibration

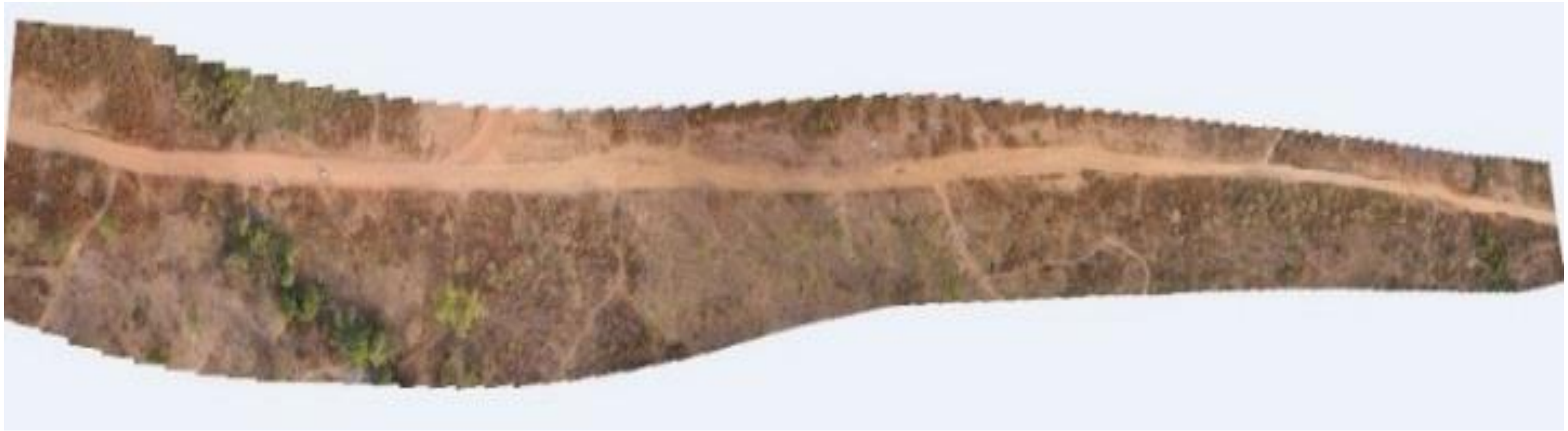


Absolute orientation showing ground control

Experimental results

The four steps procedure mentioned was evaluated using data collected from a low-cost UAV.

Our results show that, the 2-D planimetric accuracy when compared with the 6 control points is between 3 to 5 metres.



Mosaicked images covering test area

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Conclusions

- Our method for ortho-rectification, although, is automatic but is not autonomous, it does not require significant operator interaction.

- Error assessment during the matching of conjugates on frames shows that the image RMS residual is small.

- Cost and turnaround time for production of ortho-rectified mosaics are quite small when compared with the traditional method.

References

1. M. Kontitsis, M., Valavanis, K., N. Tsourveloudis , “A UAV Vision System for Airborne Surveillance,” In Proc. of the IEEE International Conference on Robotics and Automation, 2004, pp. 77–83.
2. D.W. Casbeer, D.B. Kingston, R.W. Bear , T.W. McLain, and S.M. Li, “Cooperative Forest Fire Surveillance Using a Team of Small Unmanned Air Vehicles.”, Intl. Journal of System Science, January 2005, pp 1-18.
3. B.O. Olawale, C.R. Chatwin, R.C.D. Young, P.M. Birch,“Real-Time Monitoring Of Buried Oil Pipeline Right-Of-Way for Third-Party Incursion”, International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 2,February 2015, pp. 163-173.
4. B. Colfman, M. McCord, and K. Redmill, “Surface Transportation Surveillance from Unmanned Aerial Vehicles” *Proc. Of the 83rd Annual Meeting of the Transportation Research Board*, 2004.
5. J. Allen, and B. Walsh, “Enhanced Oil Spill Surveillance, Detection and Monitoring through the Applied Technology of Unmanned Air Systems”. In: *Proceedings of the 2008 international oil spill conference*.
6. R. W. Beard, T. W. McLain, D. B. Nelson, D. Kingston, and D. Johanson, “Decentralized cooperative aerial surveillance using fixed-wing miniature UAVs,” Proc. IEEE, July 2006, vol. 94, no. 7, pp. 1306–1323.
7. Fransaer, D., Vanderhaeghen, F., Everaerts, J., “PEGASUS: Business Plan for a Stratospheric Long Endurance UAV System for Remote Sensing”. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Istanbul, Turkey, GITC, Lemmer, Netherlands, 2004.
8. A. Ollero, J. Ferruz, F. Caballero, S. Hurtado, L. Merino, “Motion Compensation and Object Detection for Autonomous Helicopter Visual Navigation in the Comets System”. In: Proc. of the IEEE International Conference on Robotics and Automation, 2004, pp. 19–24.
9. Anon, “*Functional Specification for a Satellite Surveillance System*”, Andrew Palmer and Associates Report NR01003, March 2001.
10. . M.D.F Bento, “Unmanned Aerial Vehicles: An Overview. *Inside GNSS “*, February, 2008, pp. 54-61.
11. N. Mohamed, I. Jawhar, “A Fault-Tolerant Wired/Wireless Sensor Network Architecture or Monitoring Pipeline Infrastructures”, in Proc. Int. Conference on Sensor Technologies and Applications (SENSORCOMM 2008), Cap Esterel, France,25–31 August 2008; pp. 179-184.

References

12. Y. DU, P.M. Teillet, and J.Cihlar, “Radiometric Normalization of Multi-Temporal High-Resolution Satellite Images with Quality Control for Land Cover Change Detection: Remote Sensing of Environment”, 2002, pp. 123–134,
13. S. Chen, B. Mulgrew, and P. M. Grant, “A Clustering Technique for Digital Communications Channel Equalization Using Radial Basis Function Networks,” *WASET Trans. Neural Networks*, vol. 4, pp. 570–578, July 1993.
14. B. Horn *Robot Vision*, MIT Press, 1986, pp 314 – 315.
15. K. Kobayashi, C. Mori, “Relations between the Coefficients in the Projective Transformation Equations and the Orientation Element of the Photograph”. Journal of Photogrammetric Engineering and Remote Sensing. Vol. 63, No. 9, September 1997, pp.1121-1127.
16. Z. Li, J. Chen, and E. Baltsavias. Advances in Photogrammetry, Remote Sensing and Spatial Information Sciences, 2008 ISPRS Congress Book. CRC Press, Taylor & Francis Group, Boca Raton, London, New York, Leiden, p. 527.
17. E.M Mikhail, J.S. Bethel, J.C. McGlone. Introduction to Modern Photogrammetry. John Wiley & Sons Inc., New.
18. http://www.dji.com/product/spreading-wings-s800/spec (Accessed: 11 July 2013).
19. Z. Guoqing, ‘’Near Real-Time Orthorectification and Mosaic of Small UAV Video Flow for Time-Critical Event Response’ ’in Proc. o Geoscience and Remote Sensing, IEEE, 47(3), March 2009.
20. Y. I. Abdel-Aziz and H. M. Karara, “Direct Linear Transformation from Comparator Coordinates into Object Space Coordinates in Close-Range Photogrammetry,” in Proc. Symp. Close-Range Photogrammetry, Falls Church, VA, 1971, pp. 1–18, Amer. Soc. of Photogrammetry.
21. J. Skaloud, M. Cramer, and K. P. Schwarz, “Exterior Orientation by Direct Measurement of Camera and Position,” in Proc. Int. Archives Photogrammetry Remote Sens., Vienna, Austria, 1996, vol. XXXI, pp. 125-130, Part B3.
22. Gomarasca, Mario A. *Basics of Geomatics*. Dordrecht: Springer, 2009. Print

References

23. PM Birch, R Young, D Budgett, C Chatwin, “Two-pixel computer-generated hologram with a zero-twist nematic liquid-crystal spatial light modulator,” Optics letters, 25 (14), 1013-1015, 2000
24. LS Jamal-Aldin, RCD Young, CR Chatwin, “Application of nonlinearity to wavelet-transformed images to improve correlation filter performance,” Applied optics, 36 (35), 9212-9224, 1997
25. LS Jamal-Aldin, RCD Young, CR Chatwin, “Synthetic discriminant function filter employing nonlinear space-domain preprocessing on bandpass-filtered images,” Applied optics 37 (11), 2051-2062, 1998
26. CG Ho, RCD Young, CD Bradfield, CR Chatwin, “A fast Hough transform for parameterisation of straight lines using fourier methods,” Real-Time Imaging, (2), 113-127, 2000.
27. CR Chatwin, M Farsari, S Huang, MI Heywood, RCD Young, PM Birch, F Claret-Tournier, JD Richardson, “Characterisation of epoxy resins for microstereolithographic rapid prototyping,” The International Journal of Advanced Manufacturing Technology, 15 (4), 281-286, 1999
28. CG Ho, RCD Young, CR Chatwin, “Sensor geometry and sampling methods for space-variant image processing,” Pattern Analysis & Applications, 5 (4), 369-384, 2002
29. H Waqas, N Bangalore, P Birch, R Young, CH Chatwin, “An Adaptive Sample Count Particle Filter,” Journal of Computer Vision and Image Understanding, 116 (12), 1208-1222, 2012
30. 20) M.N.A. Khan, C.R. Chatwin, R.C.D. Young, “A framework for post-event timeline reconstruction using neural networks,” digital investigation, 4 (3), 146 -157, 2007
31. 21) RKK Wang, CR Chatwin, L Shang, “Synthetic discriminant function fringe-adjusted joint transform correlator,” Optical Engineering, 34 (10), 2935-2944, 1995
32. P Birch, R Young, D Budgett, C Chatwin, “Dynamic complex wave-front modulation with an analog spatial light modulator,” Optics letters 26 (12), 920-922, 2001
33. PM Birch, D Budgett, R Young, C Chatwin, “Optical and electronic design of a hybrid digital-optical correlator system,” Optical Engineering, 41 (1), 32-40, 2002

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Thank you